RP 105 Factors Indicating Gear Lube Oil Change

The following recommended practice (RP) is subject to the disclaimer at the front of this manual. It is important that users read the disclaimer before considering adoption of any portion of this recommended practice.

This recommended practice was prepared by a committee of the AWEA Operations and Maintenance (O&M) Committee.

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Purpose and Scope

The scope of "Factors Indicating Gear Lube Oil Change" addresses the determining factors that could indicate a gear lube oil change is required.

Introduction

There are many factors that could cause an oil change in a wind turbine gearbox. This paper will provide factors to consider that contribute to a condition-based gear oil change. The decision to perform a condition-based oil change is founded on the overall condition of the oil which is evaluated using turbine and gearbox manufacturer condemning limits and industry standards. In some cases, filtration or dehydration corrective actions may be employed to extend the service life of the oil.

Factors Indicating Gear Lube Oil Change

1. Contamination

1.1. Externally Generated Contamination

External contamination particles can be derived from the environment or incompatible substances added to the oil. These include ingress of water due to weather conditions and natural aspiration through a breather, or salt spray, sand, dirt, dust, clay, silicates, and incompatible lubricants. Some contaminants may react adversely with oil additive packages in the lubricant, thus damaging lubricant quality and may not be able to be remedied by filtration and may even require a system flush.

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1. Contamination
(continued)

1.2. Internally Generated Contamination
In some cases internally generated contaminants have the same characteristics as the external type. Internally generated contamination consists of wear debris particles, decomposition sludge, and oxidation byproducts.

2. Lubricant Degradation

Additive degradation, in some cases is known as additive depletion. Some lubricant types may have slightly reduced additives while staying within acceptable limits and are still serviceable. Other lubricant types may be characterized by the reduced ability of the oil's additive system to perform its intended function. Once depleted, organic acids may form, creating sediment, sludge, or varnish particles that can cause deposits and increase the viscosity of the oil, makeup oil, or even after an oil change if not flushed properly.

3. General Guidelines For Lube Oil Changes

By necessity these guidelines are general in nature. These limits and/or rules cannot cover every conceivable situation, but are meant to be a guide for you to make cost effective and reasonable corrective actions. These guidelines are consistent with *ANSI/AGMA/AWEA 6006-A03, Standard for Design and Specification of Gearboxes for Wind Turbines* or *IEC ISO 61400-4-2012*.

3.1. Water Contamination
Water is always present in some minute amount. There are different phases for water in oil:

1. In solution (not visible to the unaided eye).
2. Emulsified (causing the oil to appear hazy or milky).
3. Free (settling on the bottom of the gear case or sample bottle).

Different phases are dependent on several factors such as oil and additive types, amount of water present, and the temperature of the oil when it is observed

AWEA 6006-A03 outlines water levels at 500 ppm (0.05%) as borderline and 1000 ppm (0.10%) as unsatisfactory[1, Tab. F.4], however water saturation levels change with temperature fluctuations, i.e. warm oil holds more water than cold oil. This means that water in solution at hot temperature could cause some water to become free water when the oil cools from turbine down time. Water levels change with season and climate making it important to use the AWEA recommended ASTM test method, *D6304-C* outlined in the AWEA recommended practice *"Wind Turbine Gear Oil Analysis Test Methods"*.

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3.1. Water Contamination
(continued)

Water at elevated parts per million may contribute to[1, Tab. F.4]:

- Accelerated additive depletion
- Accelerated oxidation
- Interfere with an active lubricant film formation
- May react with additives to form residue on critical surfaces and plug filters or clog spray nozzles
- May react with the base fluid or additives to promote the hardening of elastomers or premature failure of internal coatings such as paints
- May react with base fluid where additives can increase acidity
- Direct contact with metal surfaces can produce rust particles that contribute to abrasive wear and act as an oxidation catalyst
- Corrosion etch pits may initiate fatigue cracks
- Under specific conditions, may lead to hydrogen embrittlement that promotes propagation of fatigue cracks

Bearing manufacturers and engineers have studied the effects that water in oil has on bearing fatigue and gear life and determined that increased water levels in wind turbine gear oil is related to increased gear wear and bearing fatigue life. A bearing manufacturer's research test provides data indicating water greater than 100 ppm (0.01%) will reduce bearing life significantly.[2,3] Another example of water in oil research is referred to as the Cantley Formula.[2,3] (*See Figure A*)

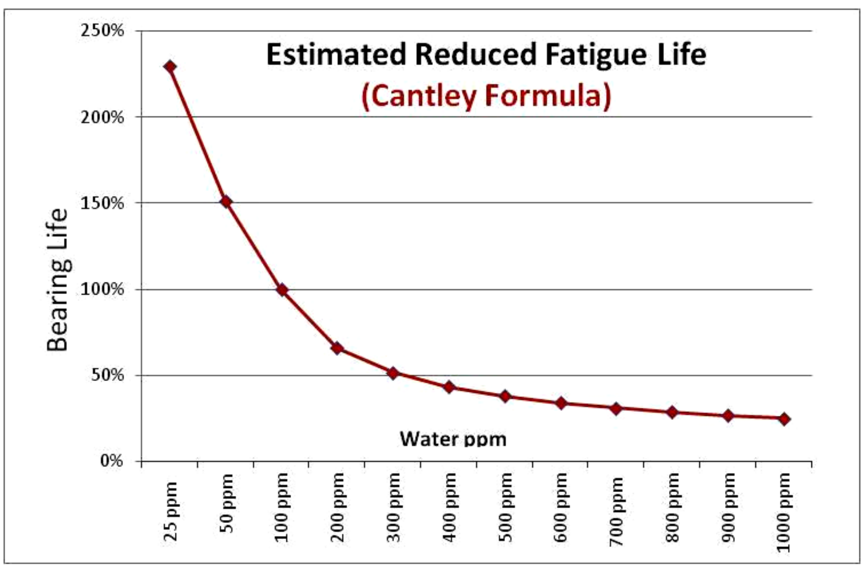

Figure A

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3.1. Water Contamination
(continued)

Cantley Formula
L = (100/X)^0.6.
X = PPM Water
L = % of Rated Bearing Life

The Cantley Formula water chart indicates that 100 ppm water in gear oil will result in 100% bearing life. It is important to keep water levels down as low as possible to optimize bearing life.

Excessive water in wind turbine gear oil has been associated with gearbox problems such as sludging, micropitting, filter plugging, and short oil and gearbox life[1, Sec. F5.3.3.2]. The IEC/ISO committee in late 2012 published the newest wind turbine standards document *IEC 61400-4-2012* which indicates lower water limit guidelines, <300 acceptable, 300 to 600 caution level, and >600 Alarm level[7, Tab. E.7], which are lower than *AWEA 6006-A03* water limits.

3.2. Particulate Levels

Particle counting for gear oil in wind turbines gearboxes is performed at laboratories by *Solid Contamination Code, ISO 4406-1999*. Particles are counted in three ranges: >4, >6, and >14 micron particle sizes, and the results are reported as x/x/x cleanliness code. Most turbine manufacturers consider that normal or target cleanliness code is -/16/13 and borderline levels are -/17/14, while levels of -/18/15 or greater are considered unsatisfactory.

Filtration has much to do with particle count. The >4 micron particle count will be reduced if the filtration is switched from the standard 10 micron filter to a 5 micron filter.

If improved filtration or installation of a new filter does not control particle contamination to the target level, this would be a condemning limit for the gear oil.

3.3. Sediment, Sludge, and Varnish Levels

Any visible sediment or discoloration is cause for unsatisfactory oil condition[1, Tab. F.4]. Verify that a clean sample is taken and visible sediment is not from the sampling process. If it is confirmed that the sample was taken without debris contamination then the source of the sediment could be from the gear oil. The source and type of contamination will determine what reasonable corrective action should take place.

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3.4. Total Acid Number Values (TAN)

Although general limits for TAN level increase above new gear oil values and vary by product chemistry type, lubricant suppliers should be able to give guidance regarding the level of TAN increase specific to their individual gear oil and at what point they consider recommending corrective action which could include changing the oil. General industry condemning limits are 2.0 over new oil value.

3.5. Viscosity Levels

The viscosity of the oil can change either up or down. The viscosity of wind turbine gear oil is normally 320 mm2/sec, formerly centistokes (cSt), which is referred to as ISO VG 320. Per the standard, each viscosity grade ranges + or – 10%. Thus for an ISO 320 fluid, the range would be 288 to 352 cSt. Results that fall outside of this range, either high or low, would not meet turbine or gearbox manufacturer's viscosity requirements and could result in a recommendation for corrective actions or oil change.

3.6. Foam Tendency

One laboratory test not normally done on wind turbine gear oils during the regular 6-month oil sampling period is the ASTM D892 foam test. Foaming can cause many issues from filter plugging to reduced oil film thickness. In this test air is blown into the test gear oil to create foam which builds up on top of the oil.[3,4] Foaming is measured at the end of the test and after a 10 minute settle time. If the foam bubbles break within the 10 minute settle time, the fluid is considered to have good foaming resistance; however, if there is any foam after the 10 minute settle time then the fluid may not be performing as designed and the oil may need to be targeted for an oil change.

4. Oil Change Condemning Limits

The factors indicating a gear oil change in Table B are general and not necessarily specific to any one gear oil. (*See Table B*) It is important to contact the oil manufacturer and ask for their specific condemning limits. These condemning limits can be used as a guide in determining when an oil change is needed.

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Table B: Factors Indicating Gear Lube Oil Change

	Method	Measure	Monitor	Change or Reconditioning
Water	Water ASTM D6304-C	ppm	300 to 600	600
Foam (@10 min settle)	ASTM D892	ml	<10	>10
Particulate Levels	Cleanliness Code	>4/>6/>14	-/17/14	-18/15
Total Acid Number	ASTM D664	mg/g KOH	1.5 over new	2.0 over new
Viscosity	STM D445	mm2/sec (cSt)	<304 or >336	<288 or >352
Sediment	Visual in oil sample			Any
Sludge or Varnish	Visual	N/A	N/A	Early filter replacements
Additive	ICP or AES oil analysis ASTM		Subject to Oil Mfg	Subject to Oil Mfg
Depletion	D5185 or ASTM D6595		Condemning limits	Condemning limits

Summary

Increased contaminants, change in lubricant physicals, and additive depletion are what to look for when evaluating whether or not gear oils need to be condemned and changed out. It is extremely important to obtain the condemning limits of the oil in use from the oil manufacturer. Applying the wrong condemning limit will cause inaccurate evaluation and skew the decision for condemning.

References

[1] *Design and Specification of Gearboxes for Wind Turbines*, ANSI/AGMA/AWEA 6006-A03 (R2010), 2010.
[2] *Timken Engineering* Manual, Timken, North Canton, Ohio, USA, 2017.
[3] *Timken Products Catalog*, Timken, North Canton, Ohio, USA, 2017, pp. A146.
[4] R. E. Cantley, “The Effect of Water in Lubricating Oil on Bearing Fatigue Life,” *ASLE Trans*, vol. 20, no. 3, pp. 244-248, 1977.
[5] fluidlife.com. “The Impact of Water Contamination on Lubricants,” 2017. [Online]. 5] Available: http://www.fluidlife.com/2017/04/16/the-impact-of-water-contamination-on-lubricants/.
[6] *Standard Test Method for Foaming Characteristics of Lubrication Oils*, ASTM D892-06, 2006.

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[7] *Wind Turbines -- Part 4: Design Requirements for Wind Turbine Gearboxes*, ISO IEC 64100-4:2012, 2012.

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